The ADAMONT method for statistical adjustment of climate projections and seasonal-to-decadal predictions applicable to energy balance land surface models

D. Verfaillie[1,2], M. Déqué[3], S. Morin[1], M. Lafaysse[1], J.-M. Soubeyroux[4], S. Bernus[4], V. Gouget[4], R. Samacoits[4], P. Lassègues[4], P. Etchevers[4], A.-L. Gibelin[4], L. Batté[3], C. Viel[4], L.-P. Caron[2], F. J. Doblas-Reyes[2]

[1]Météo-France – CNRS, CNRM UMR 3589, CEN, Grenoble, FR
[2]Barcelona Supercomputing Center, Barcelona, ES
[3]Météo-France – CNRS, CNRM UMR 3589, Toulouse, FR
[4]Météo-France – DCSC, Toulouse, FR

The issue

Strong societal demand about **climate change** impacts and its **adaptation/mitigation**

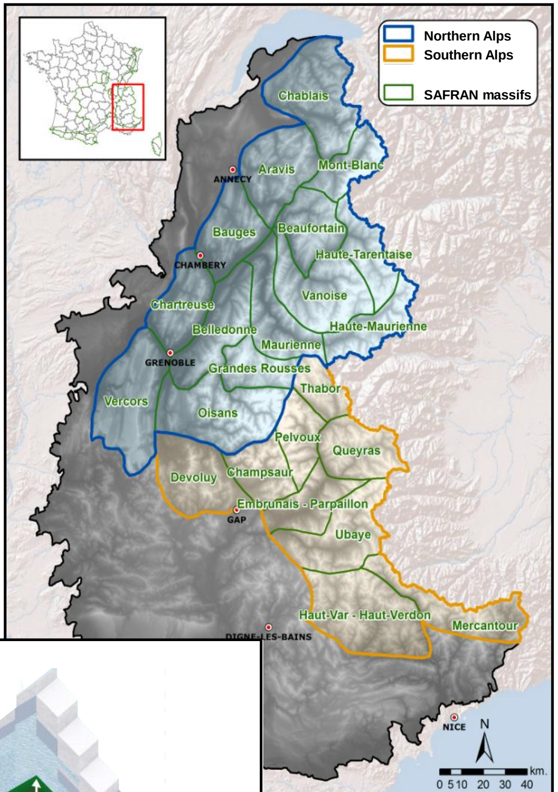
→ Need **multi-variable** climate projections at **sub-diurnal** time scales

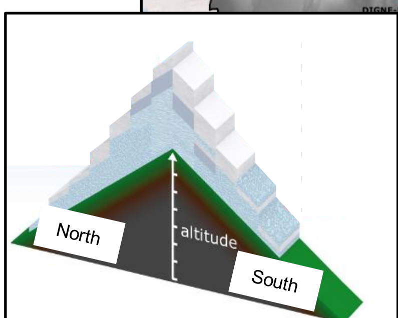
Bias-adjustment method :

- quantile mapping & weather regimes
- vs. a meteorological reanalysis (SAFRAN)
- multi-variable and hourly

Reanalysis and snow modelling

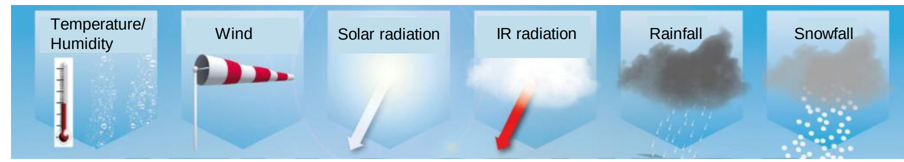
Study sites: mountain regions



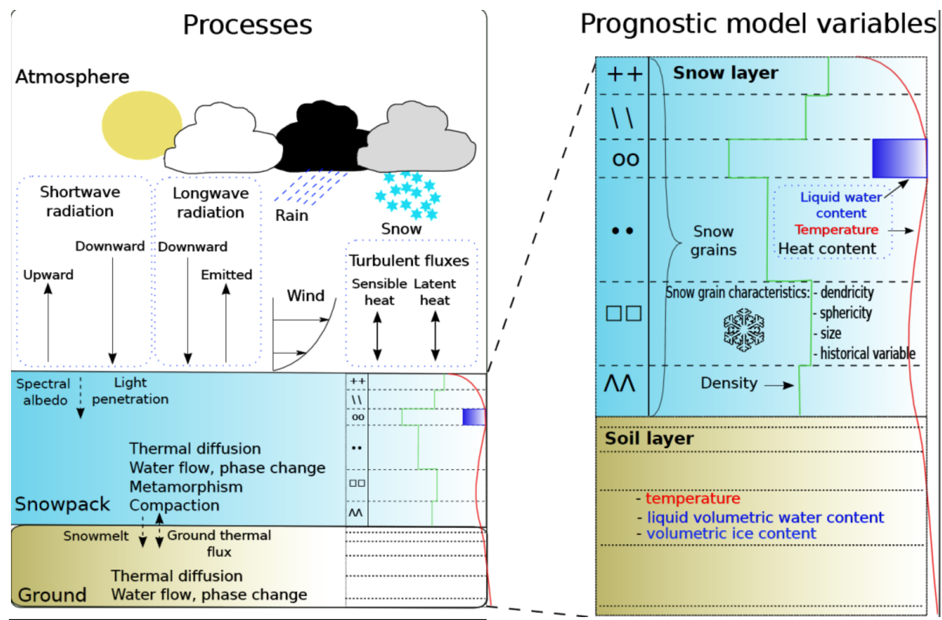


Spatial subdivision by massifs & 300 m elevation bands

Models



SAFRAN reanalysis used as « pseudo-observation »



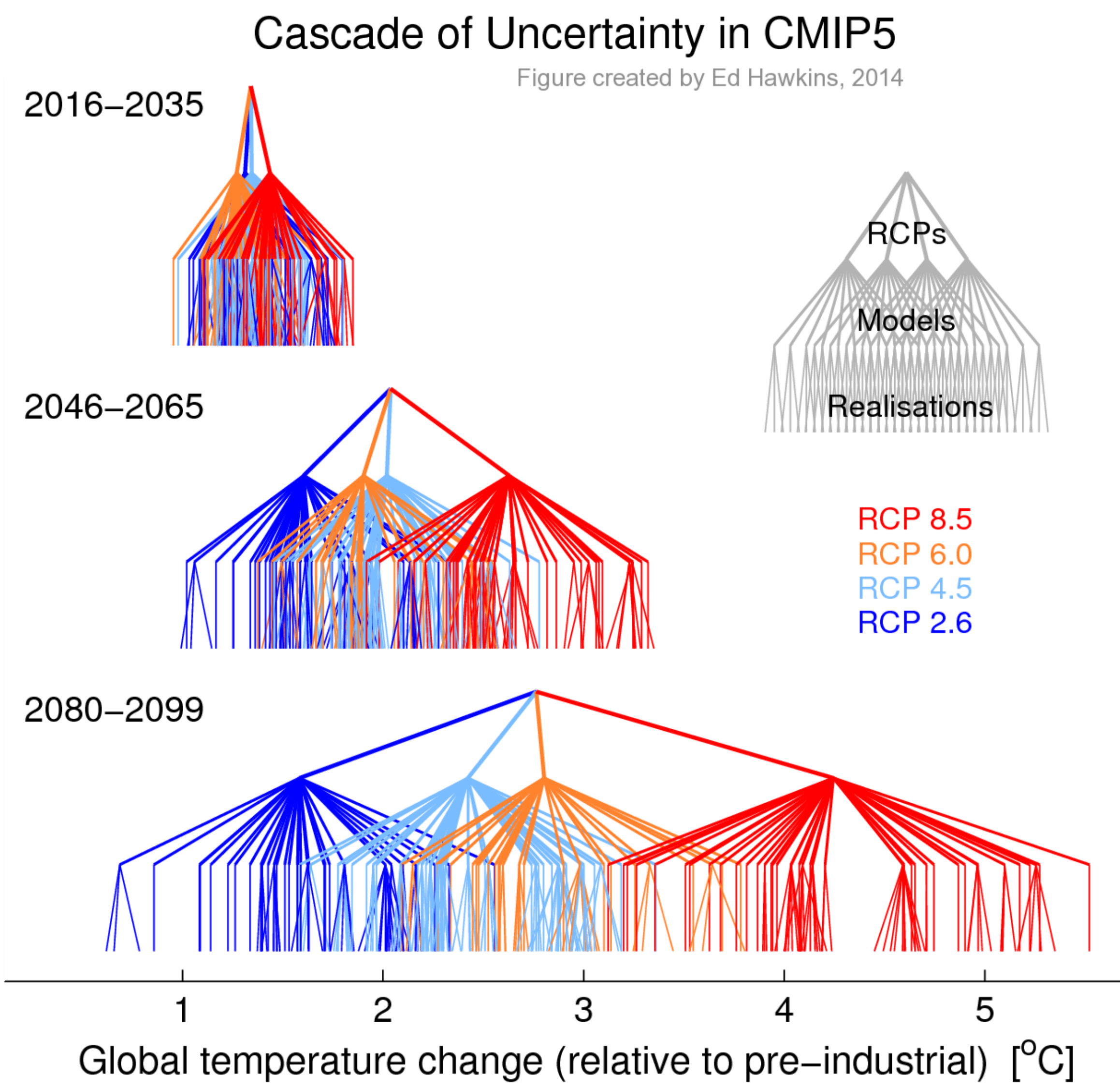
Snow model ISBA-Crocus

21^{st} century climate projections

• Global warming, what are the **local impacts** ?

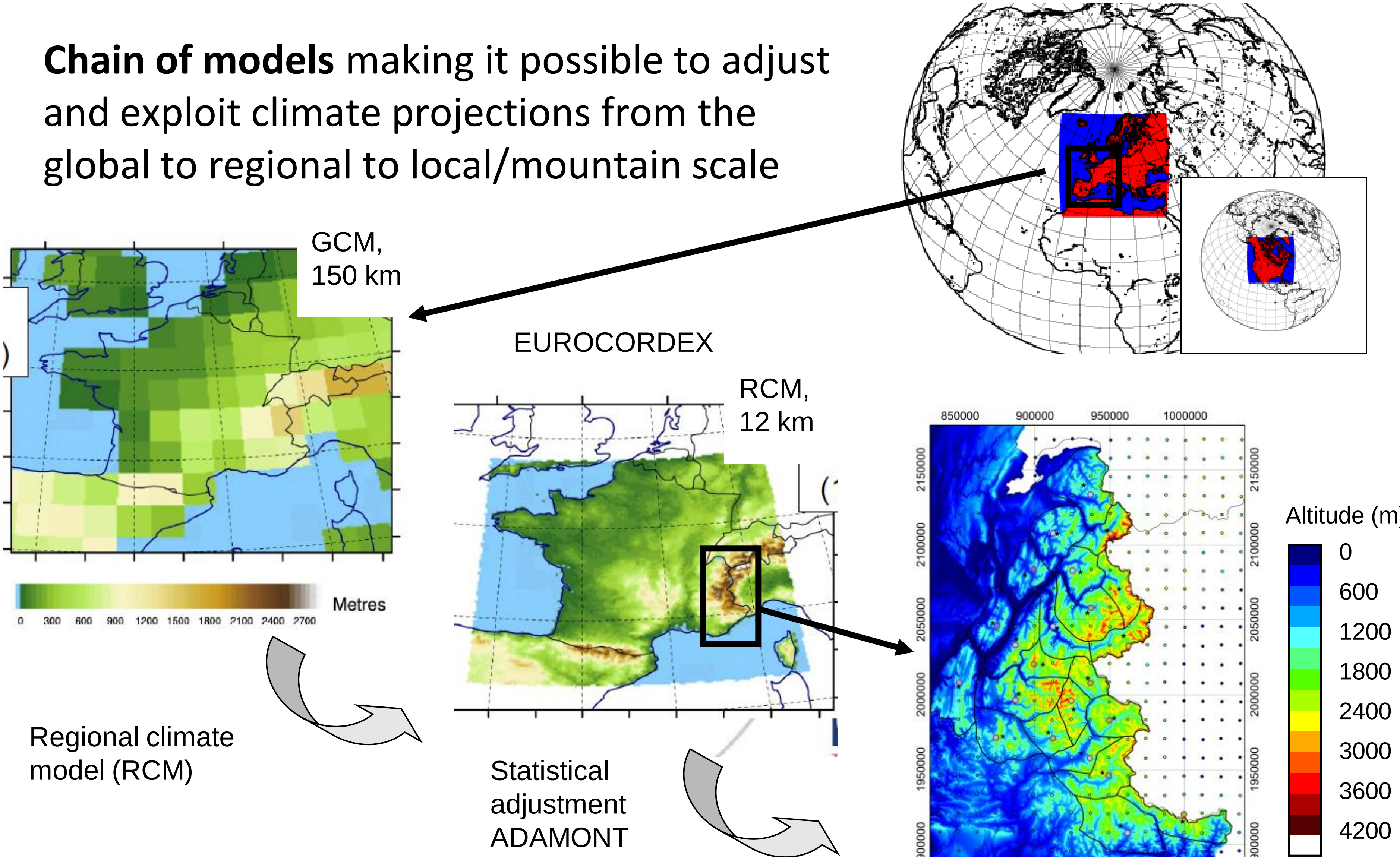
• Need to account for various greenhouse emission/concentrations pathways (**RCPs**)

• Absolute need to use an **ensemble framework**, to properly address **uncertainty** components.



21st century climate projections

Chain of models making it possible to adjust and exploit climate projections from the global to regional to local/mountain scale

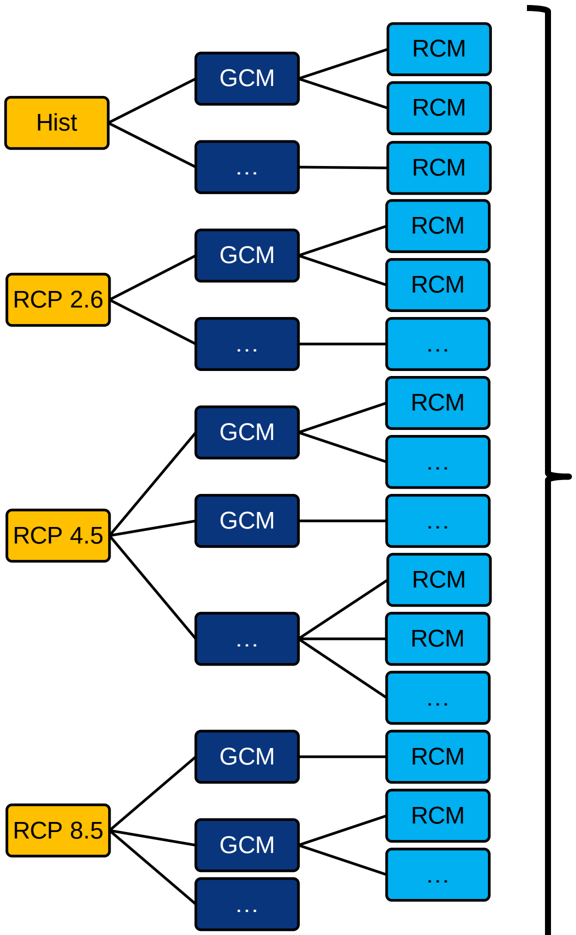


Verfaillie et al., 2017, Figure C. Cassou

The ADAMONT method

Forcing/ Scenarios

EUROCORDEX simulations



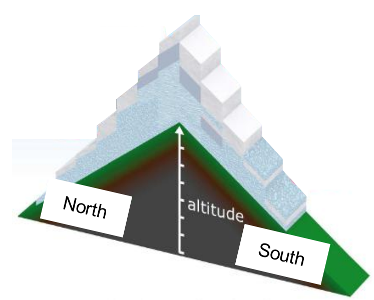
12,5 km resolution

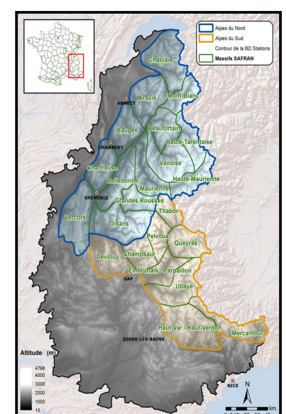
WCRP CORDEX

Q-mapping vs SAFRAN

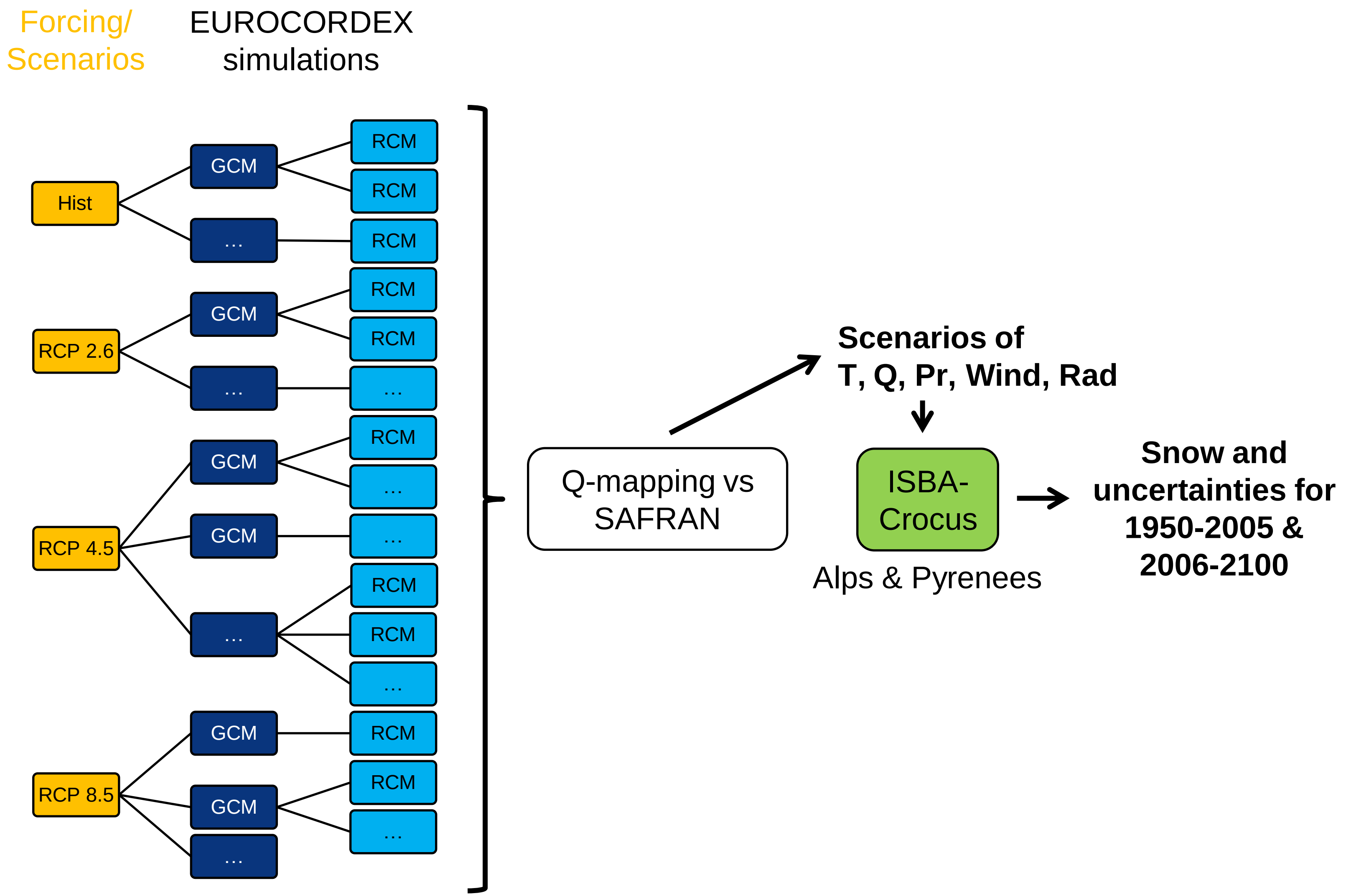
Scenarios of T, Q, Pr, Wind, Rad

Spatial subdivision by massifs & 300 m elevation bands





The ADAMONT method



The ADAMONT method

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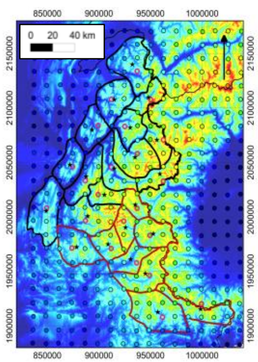

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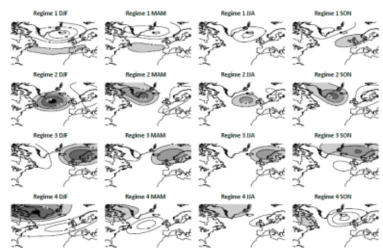

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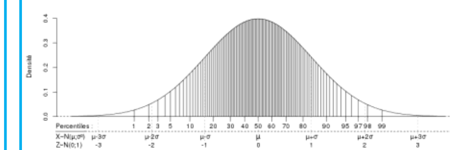
4. Percentiles of historical RCM & SAFRAN (variable, season, regime)



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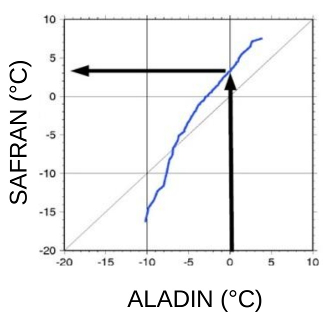

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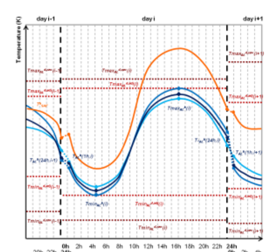

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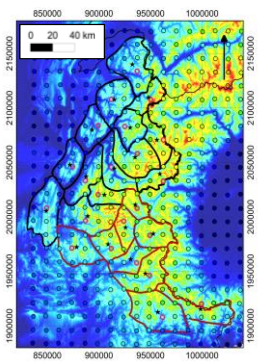

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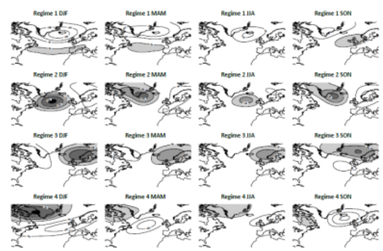

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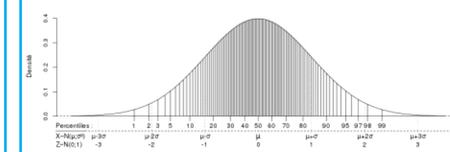

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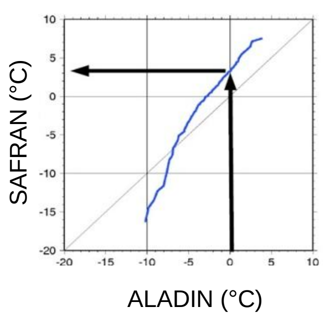

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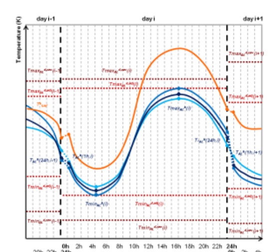

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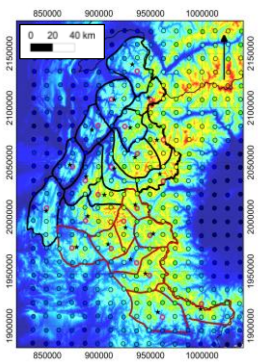

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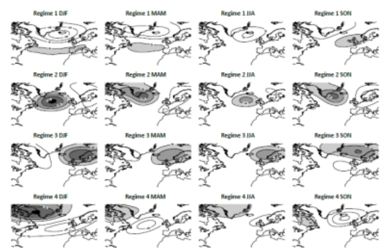

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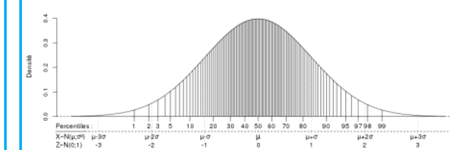

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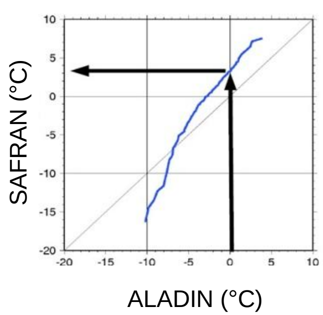

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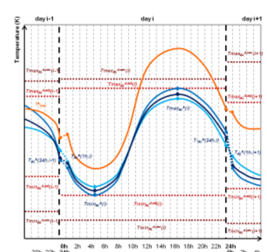

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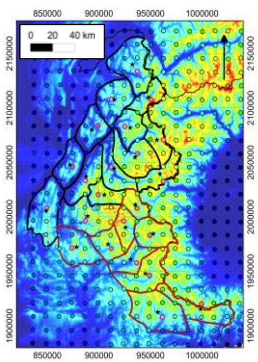

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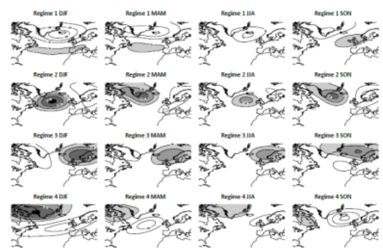

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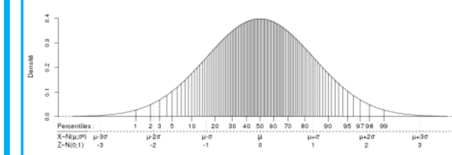

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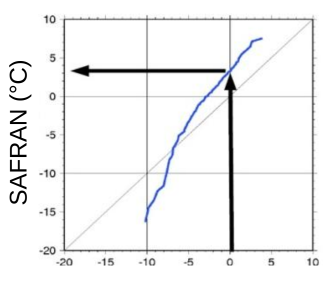

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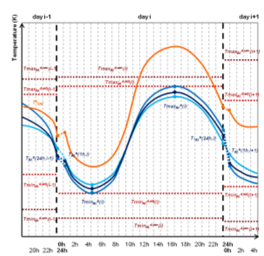

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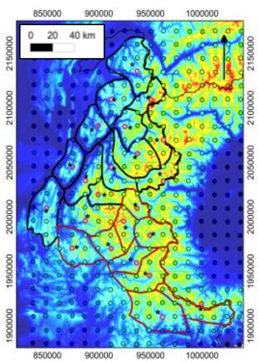

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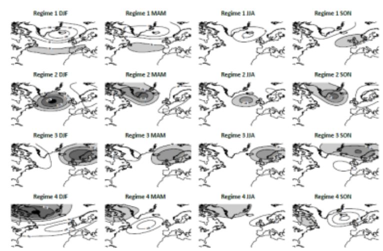

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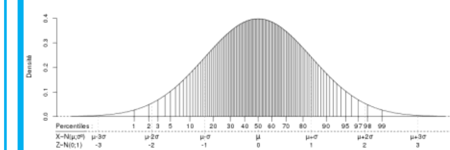

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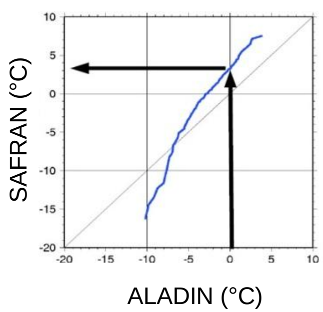

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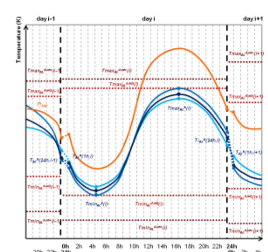

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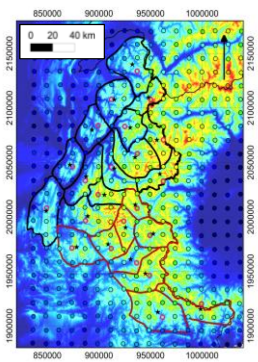

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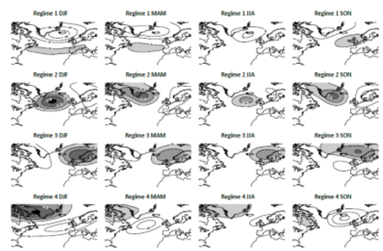

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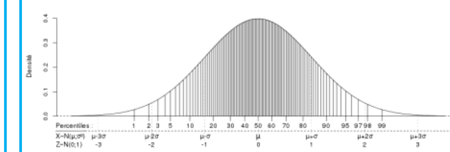

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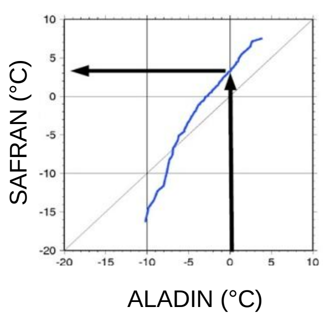

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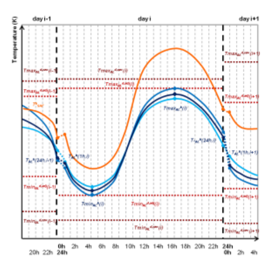

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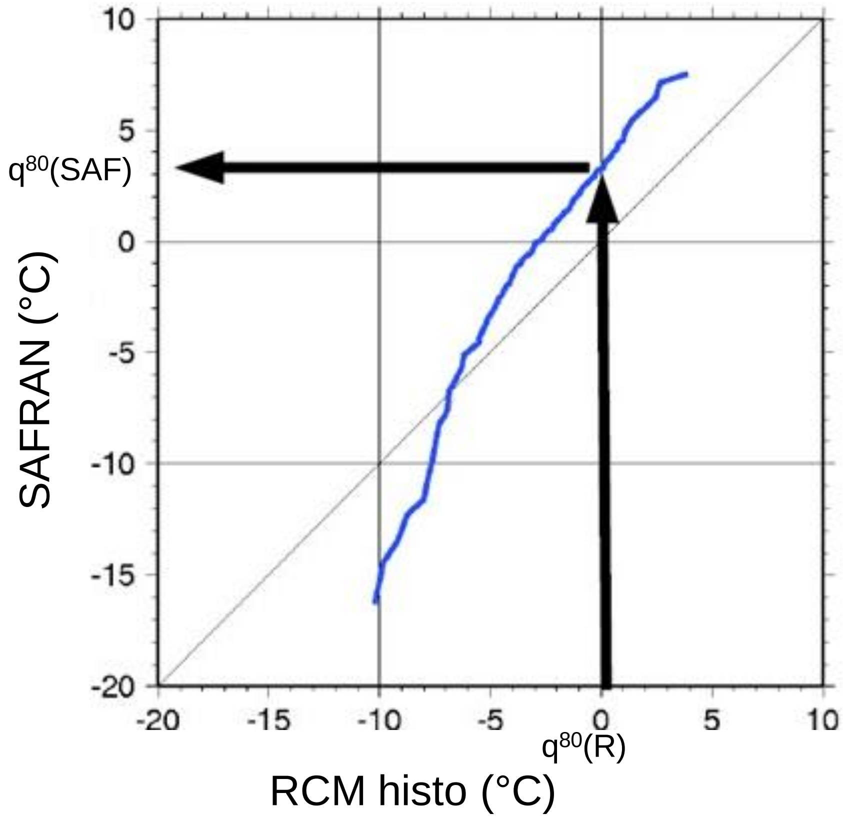
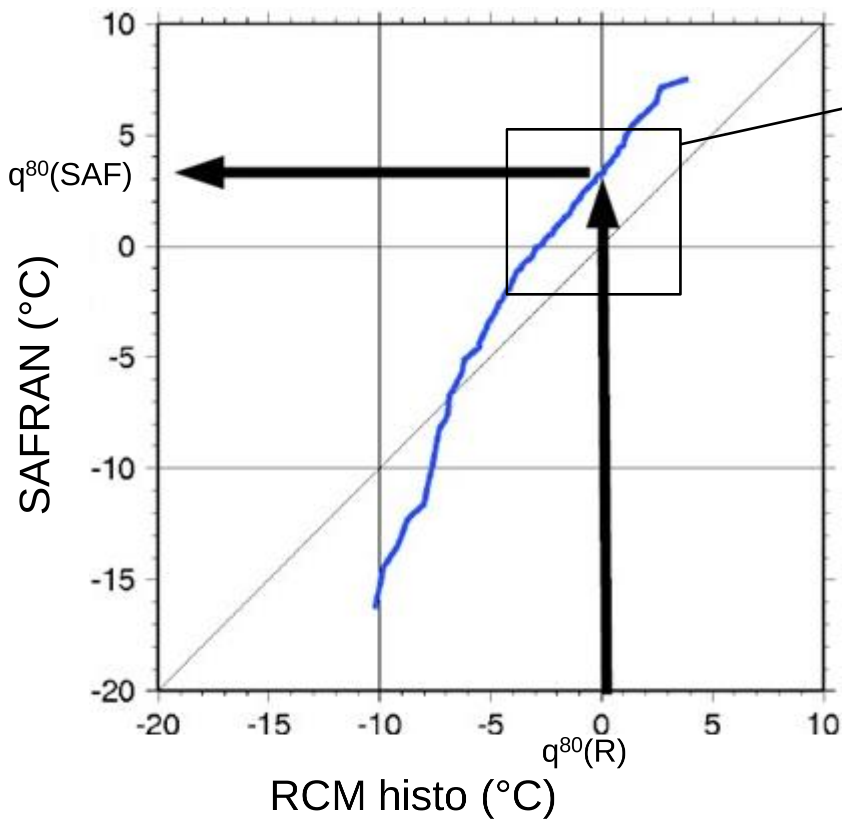
The ADAMONT method

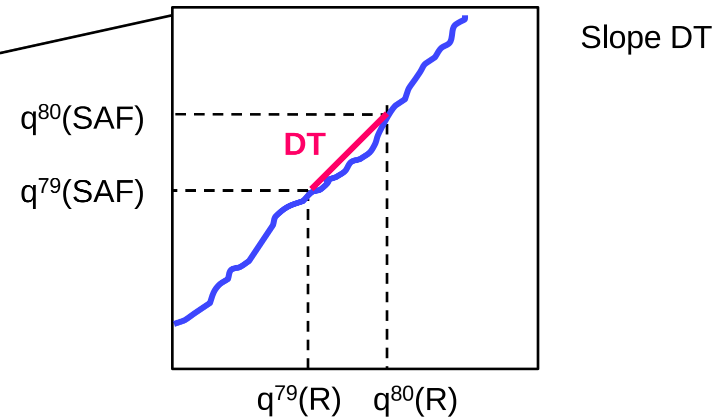
Quantile-quantile historical SAFRAN/RCM diagrams



The ADAMONT method

Adjustment of RCM values (histo + scenarios) vs. SAFRAN





Adjustment :
For a value z(R),
As soon as $q^{x}(R) \geq z(R)$:
$$\mathbf{z(R)_{corr} = q^{x-1}(SAF) + (z(R) - q^{x-1}(R)) \times DT^{x}}$$

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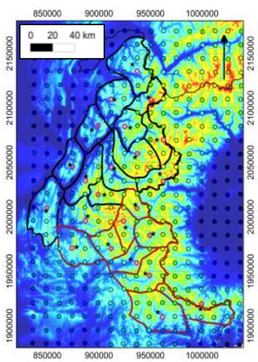

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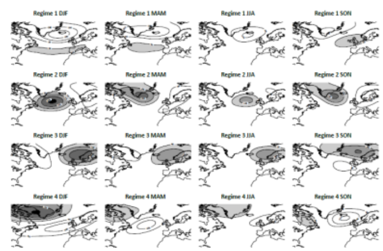

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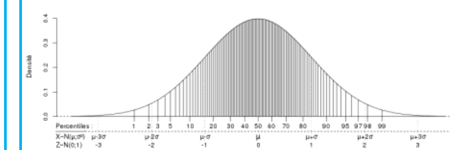

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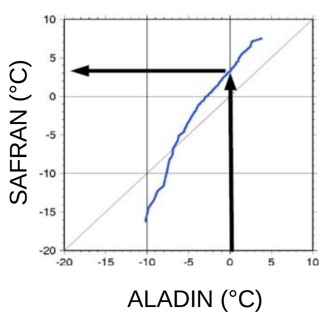

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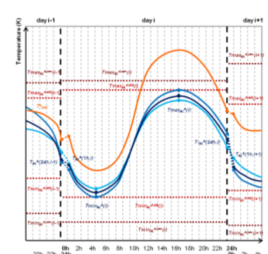

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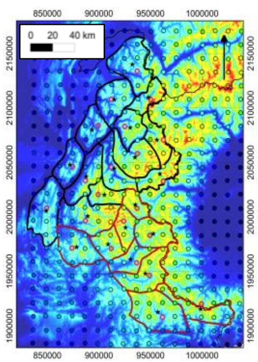

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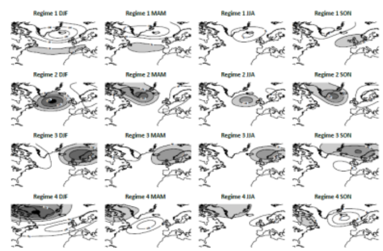

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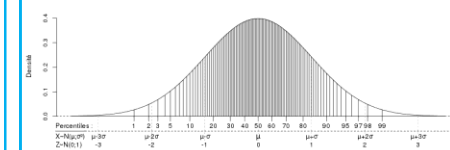

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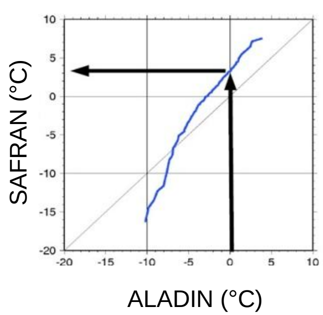

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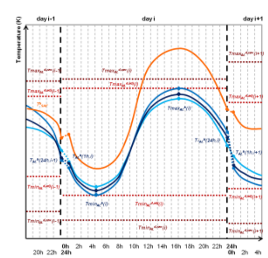

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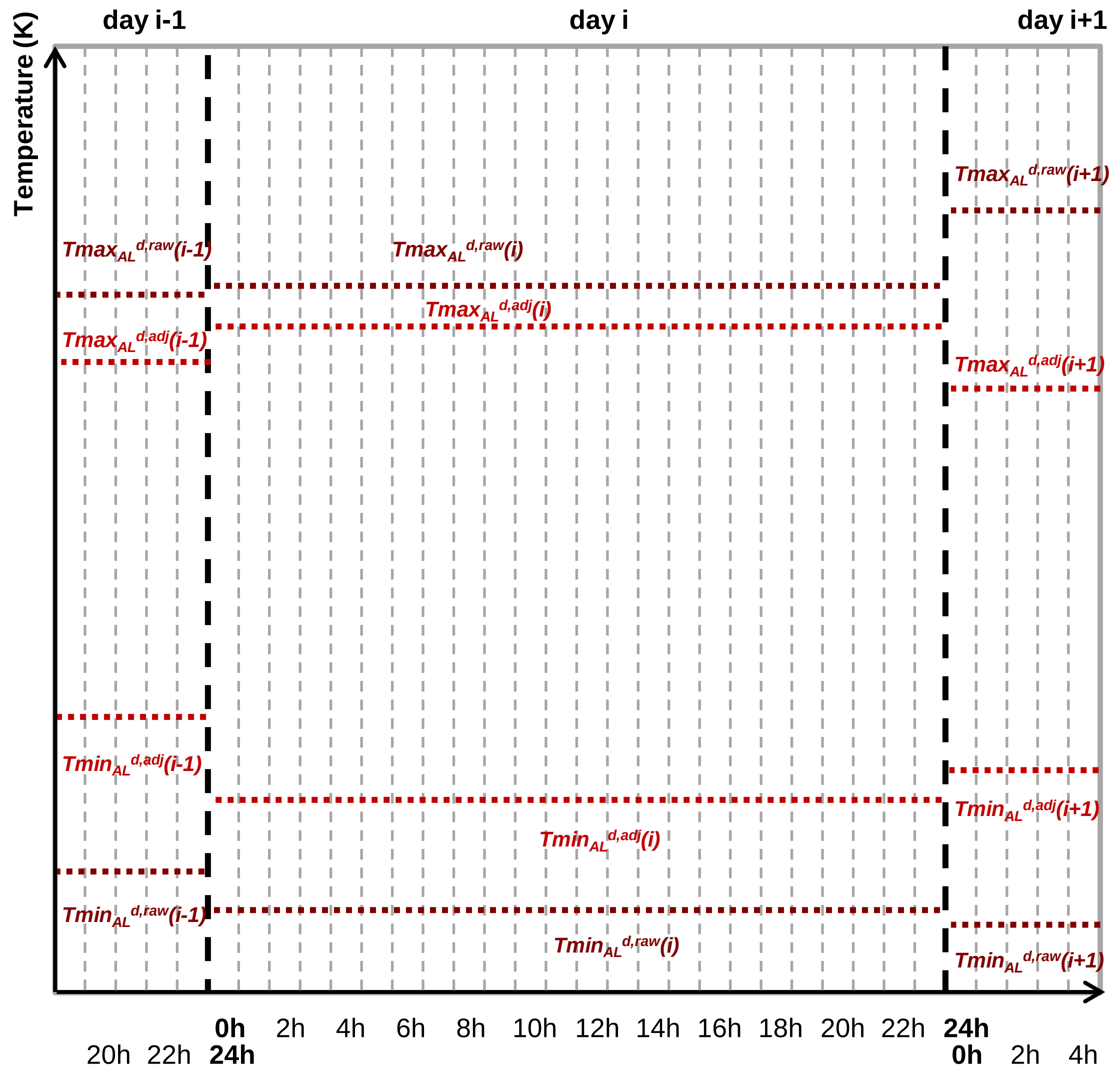
Disaggregation of adjusted RCM from daily to hourly : temperature



T_{SAF}^{h} : hourly T from SAFRAN analog
T_{AL}^{h} : hourly adjusted ALADIN T, with
α = 0
α = 2 (final value)
α = ∞
$Tmin/max_{AL}^{d,raw}$: daily min/max raw ALADIN T
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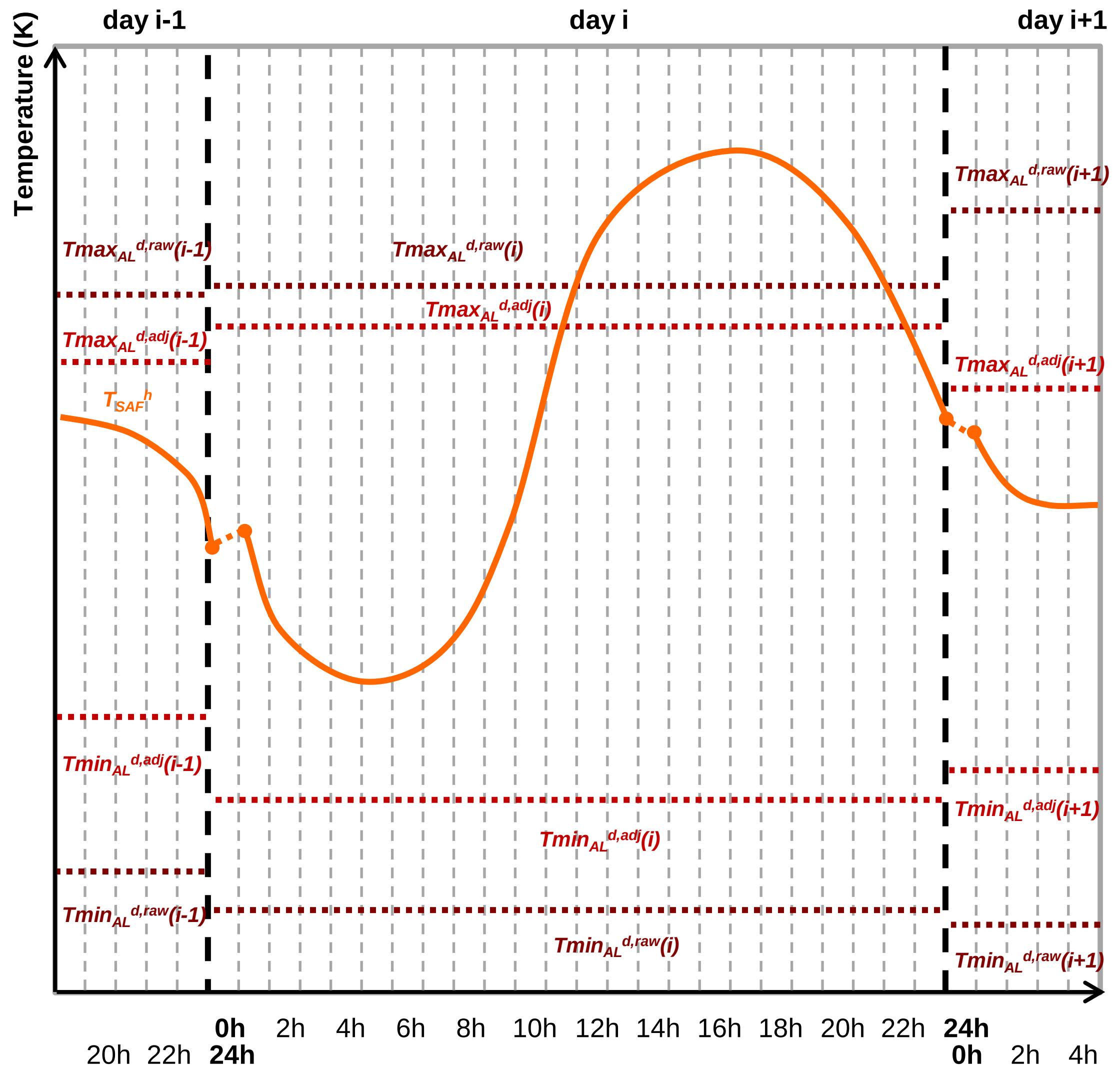

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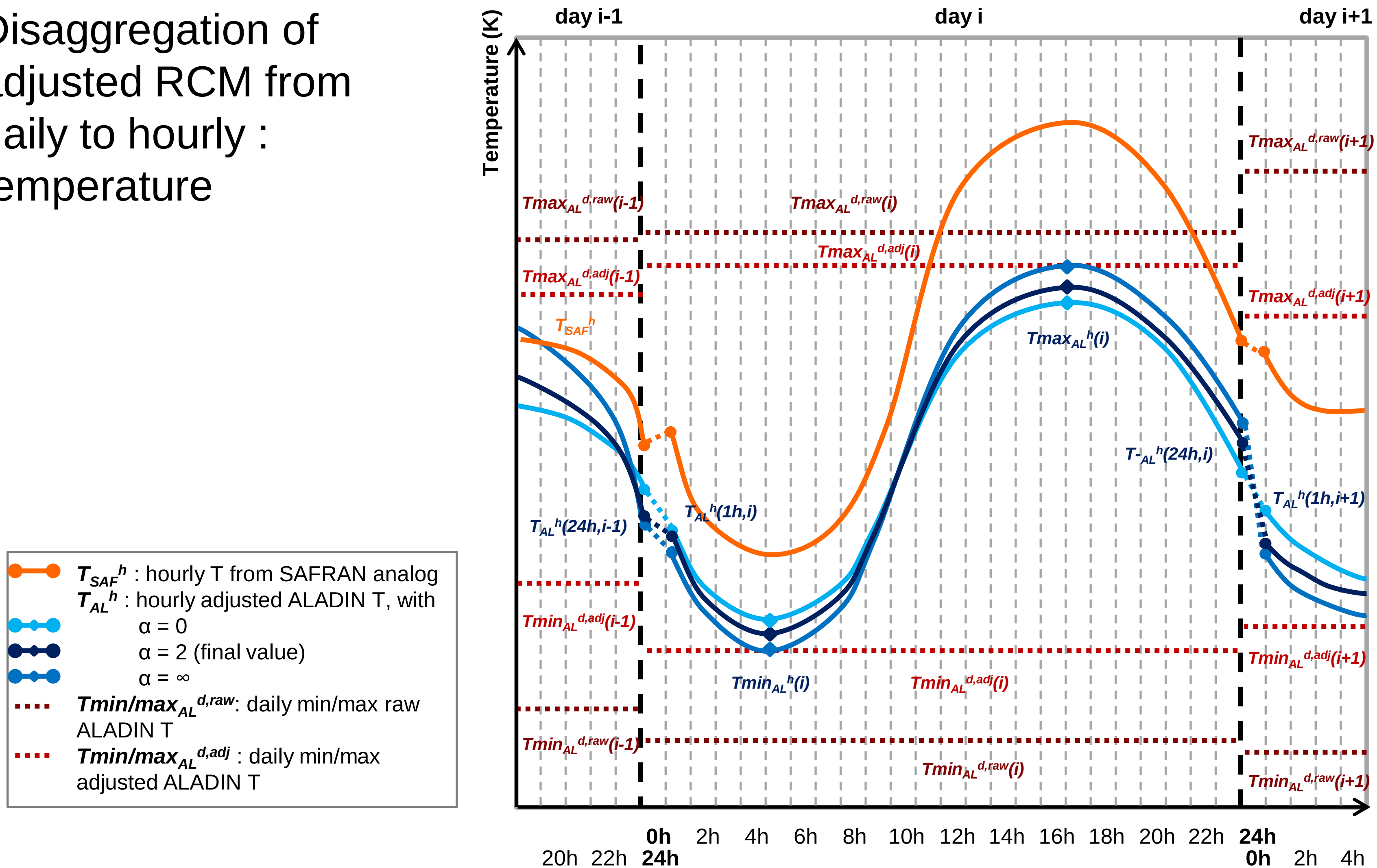
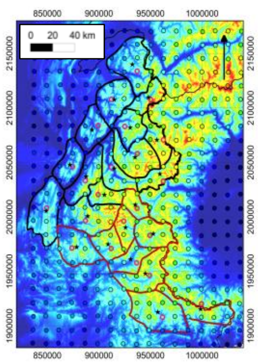
Disaggregation of adjusted RCM from daily to hourly : temperature

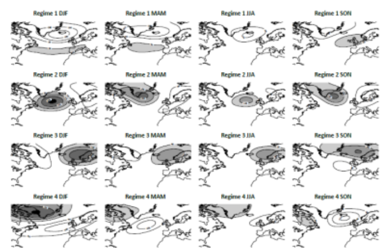


The ADAMONT method

1. Neighbouring RCM grid points

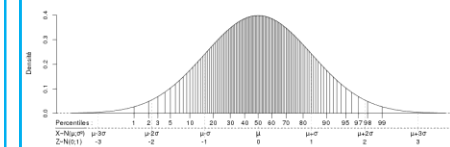


2. RCM & ERA-Interim regimes

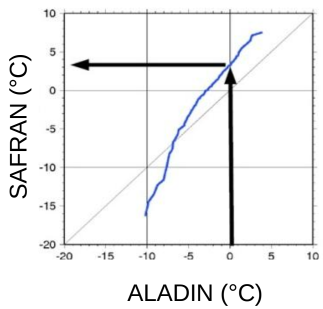


3. SAFRAN : 1h → daily

4. Percentiles of historical RCM & SAFRAN (variable, season, regime)

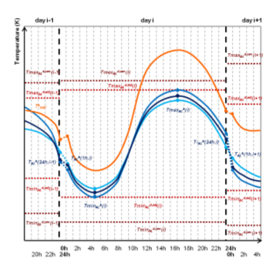


5. Quantile mapping (variable, season, regime)



6. SAFRAN analogous days, criteria:
- same month
- same regime
- coherent Pr.
- consecutive days (when possible)

7. Adjusted RCM : daily → 1h (shape from SAFRAN analogues)



8. Total precipitation separation into rain and snow (1°C threshold) + additional quantile mapping of rain and snow separately

The ADAMONT method

Evaluated in a recent paper:

Verfaillie, D., Déqué, M., Morin, S., and Lafaysse, M.: The method ADAMONT v1.0 for statistical adjustment of climate projections applicable to energy balance land surface models, Geosci. Model Dev., 10, 4257-4283, https://doi.org/10.5194/gmd-10-4257-2017, 2017.

Geosci. Model Dev., 10, 4257–4283, 2017
https://doi.org/10.5194/gmd-10-4257-2017

Geoscientific
Model Development
Open Access
EGU

The method ADAMONT v1.0 for statistical adjustment of climate projections applicable to energy balance land surface models

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Received: 9 June 2017 – Discussion started: 17 July 2017
Revised: 18 September 2017 – Accepted: 18 October 2017 – Published: 24 November 2017

A few results

- **13 GCM/RCM pairs** covering RCP4.5 and RCP8.5 (4 feature RCP2.6)
- HIST: 1950-2005, RCP: 2005-2100 → 3500+ simulation years

RCM (Institute) / GCM	Period	CNRM-CM5	EC-EARTH	HadGEM2-ES	MPI-ESM-LR	IPSL-CM5A-MR
CCLM 4.8.17 (CLMcom)	HIST	1950–2005	1950–2005	1981–2005	1950–2005	
	RCPs	2006–2100	2006–2100	2006–2099	2006–2100	
ALADIN 53 (CNRM)	HIST	1950–2005				
	RCPs	**2006–2100**				
WRF 3.3.1F (IPSL-INERIS)	HIST					1951–2005
	RCPs					2006–2100
RACMO 2.2E (KNMI)	HIST			1981–2005		
	RCPs			**2006–2099**		
REMO 2009 (MPI-CSC)	HIST				1950–2005	
	RCPs				**2006–2100**	
RCA 4 (SMHI)	HIST	1970–2005	1970–2005	1981–2005	1970–2005	1970–2005
	RCPs	2006–2100	**2006–2100**	2006–2099	2006–2100	2006–2100

- Use of **ISBA-Crocus** model to compute snow conditions
- Definition of annual scale **indicators** characterising atmospheric and snow conditions (mean, days above threshold etc.)
- Statistical framework to handle multi-scenario multi-annual multi-GCM/RCM pairs (+ multiphysics Crocus version, not shown here)

A few results

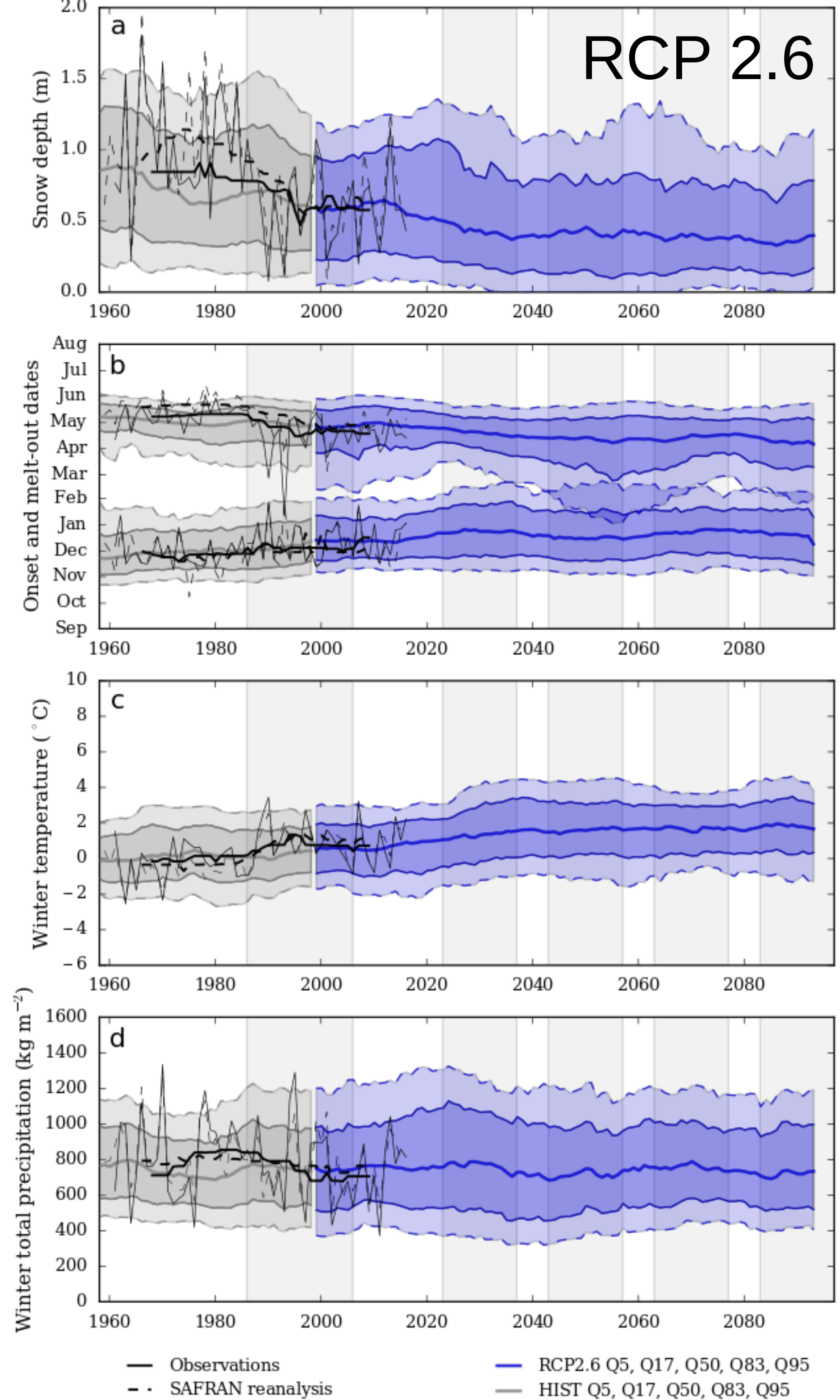
Climate projections for natural snow on the ground

→ Sustained interannual variability

→ Increased snow scarcity

→ RCP differenciation after 2050

Verfaillie, D., Lafaysse, M., Déqué, M., Eckert, N., Lejeune, Y., and Morin, S.: Multi-component ensembles of future meteorological and natural snow conditions for 1500 m altitude in the Chartreuse mountain range, Northern French Alps, The Cryosphere, 12, 1249-1271, https://doi.org/10.5194/tc-12-1249-2018, 2018.



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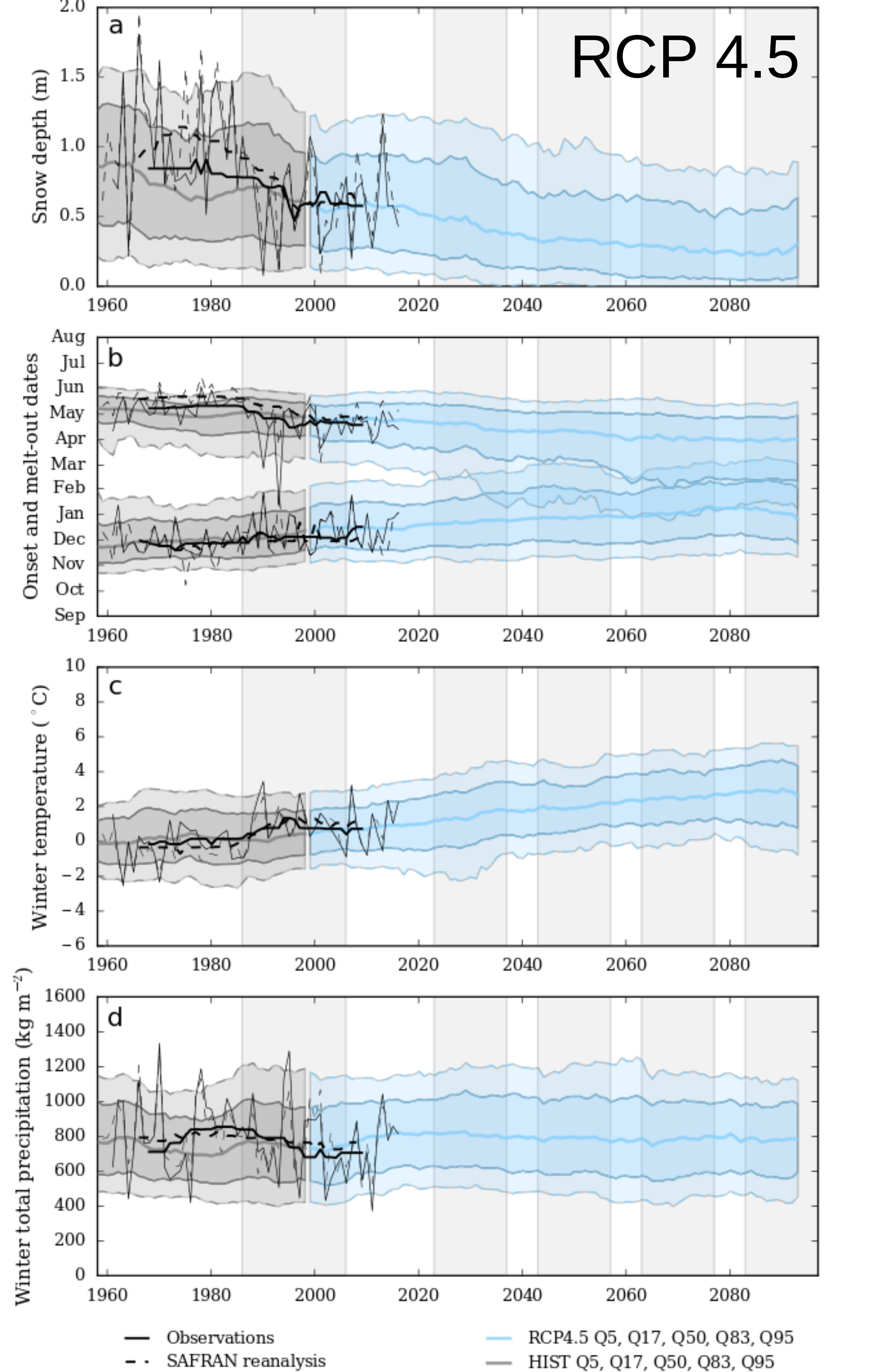

A few results

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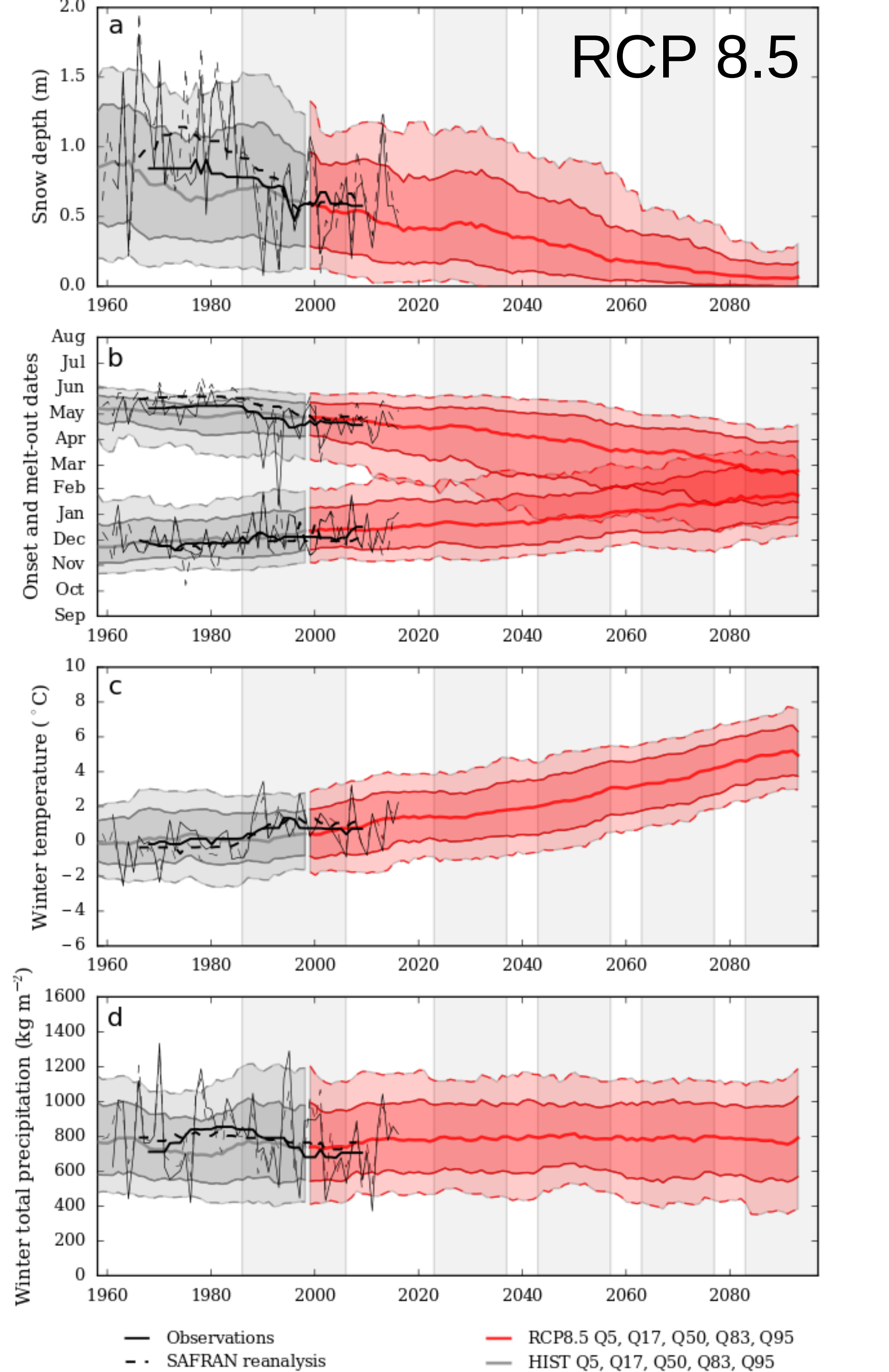
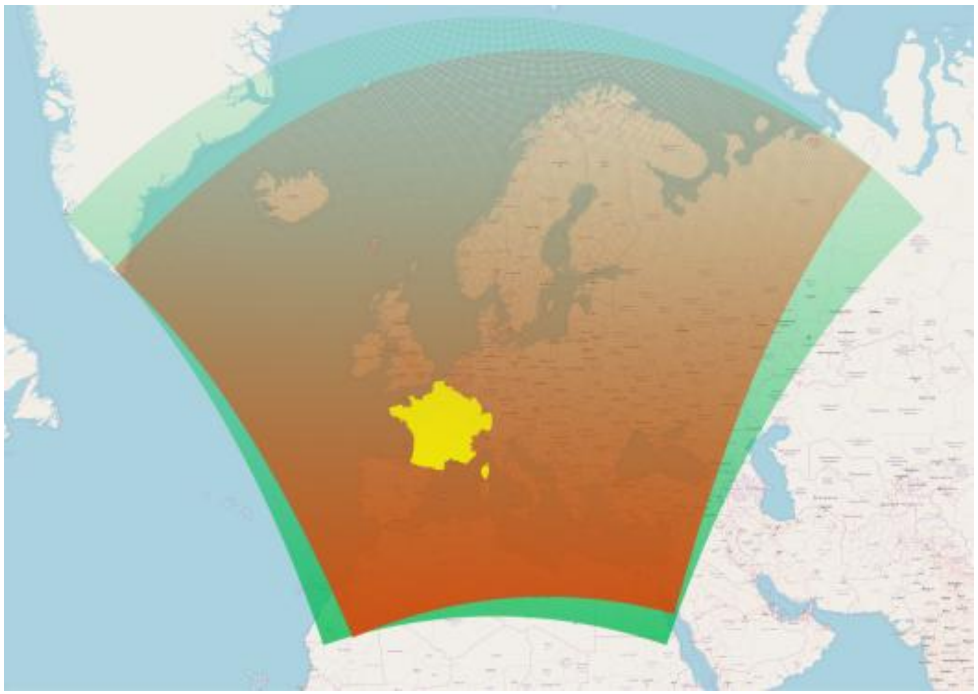


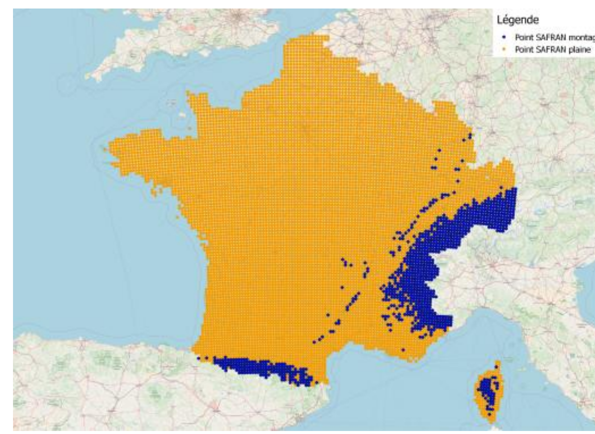
Verfaillie, D., Lafaysse, M., Déqué, M., Eckert, N., Lejeune, Y., and Morin, S.: Multi-component ensembles of future meteorological and natural snow conditions for 1500 m altitude in the Chartreuse mountain range, Northern French Alps, The Cryosphere, 12, 1249-1271, https://doi.org/10.5194/tc-12-1249-2018, 2018.

Perspectives

- Application of ADAMONT for **entire France**



Green: CNRM-ALADIN grid
Red : EUR-11 grid
Yellow: SAFRAN-France grid



Downscaling on the SAFRAN-France grid (~10 000 points) and **statistical adjustment**

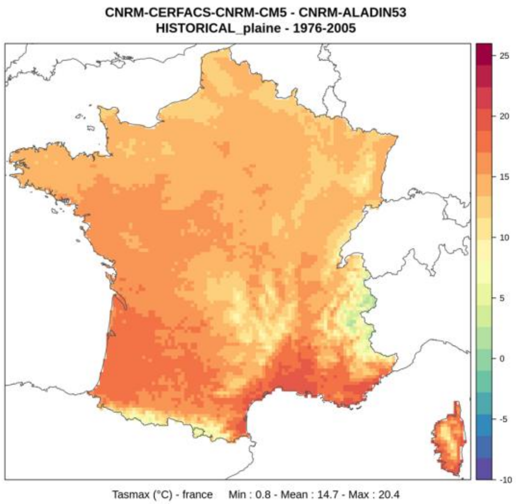
Modification of original code for time disaggregation of direct/diffuse radiation, humidity and precipitation

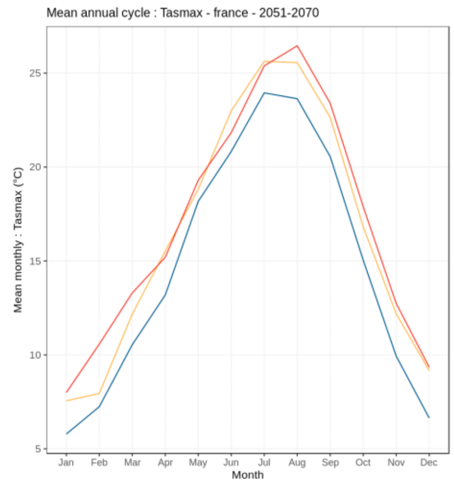
Perspectives

METEO FRANCE

- Application of ADAMONT for **entire France** – First results

HISTORICAL 1976-2005

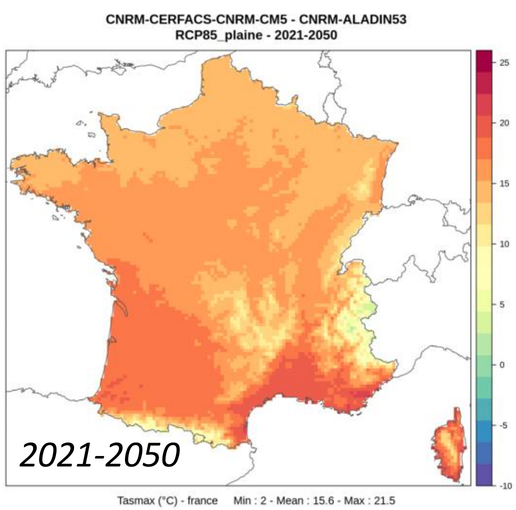


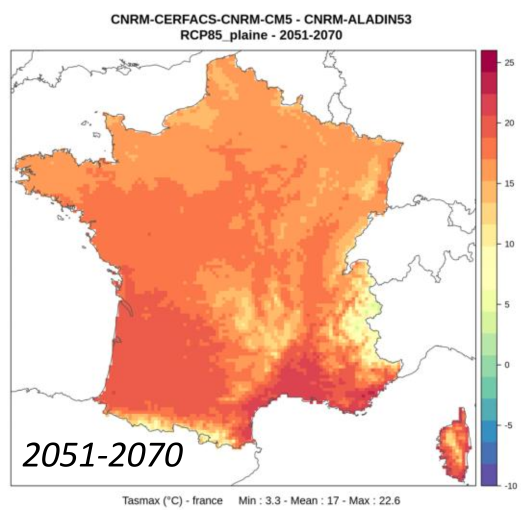


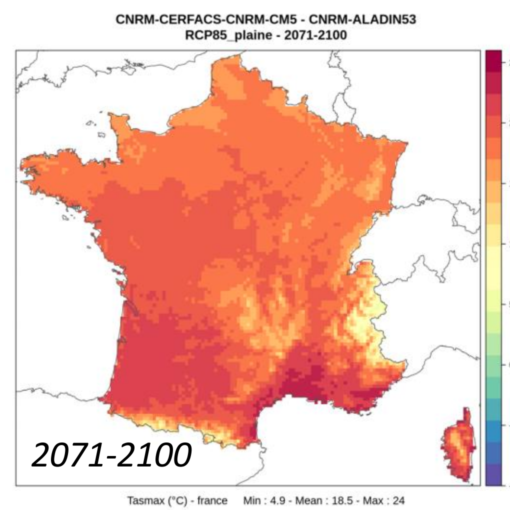
Maximum T
CNRM-ALADIN53 /
CNRM-CERFACS-CNRM-CM5

Blue: HISTORICAL 1976-2005
Yellow: RCP 4.5 2051-2070
Red : RCP 8.5 2051-2070

RCP 8.5



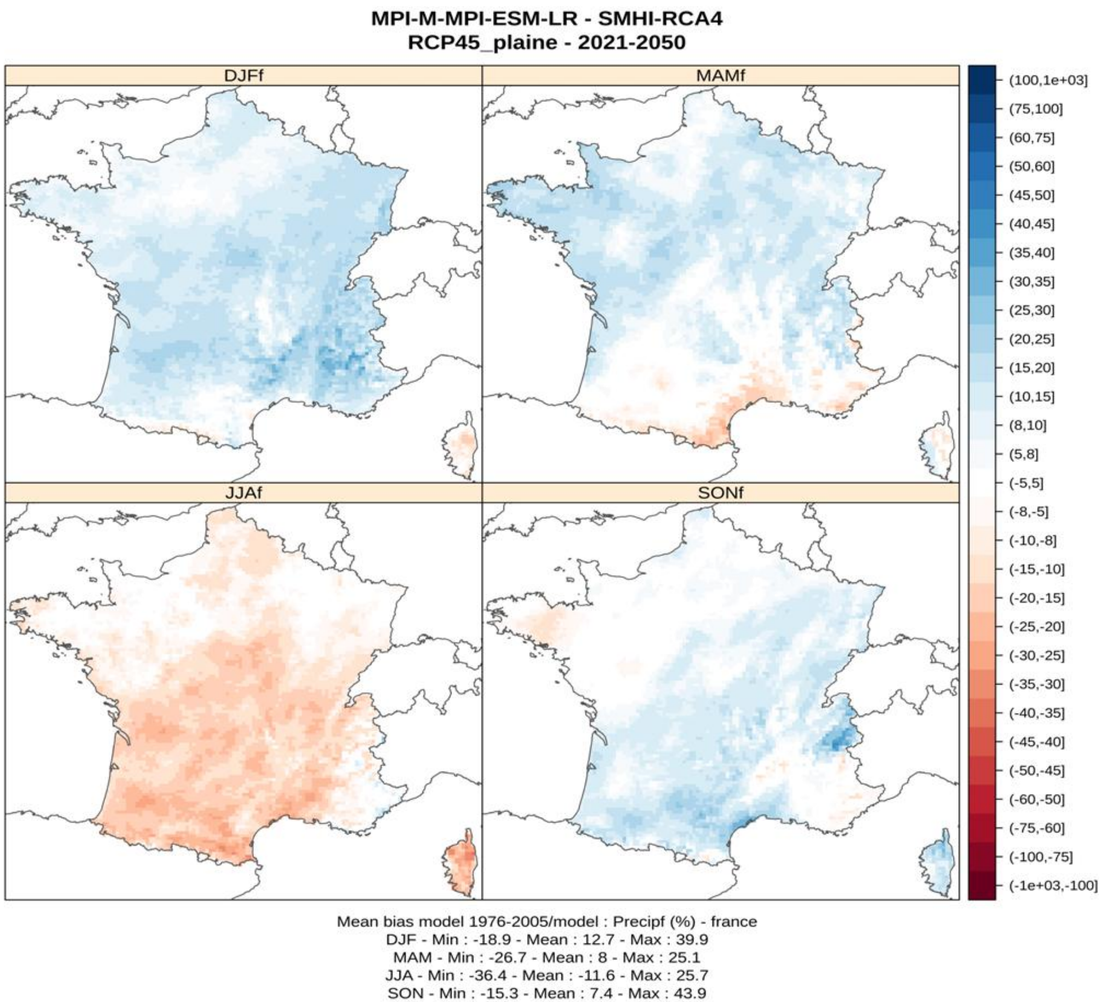




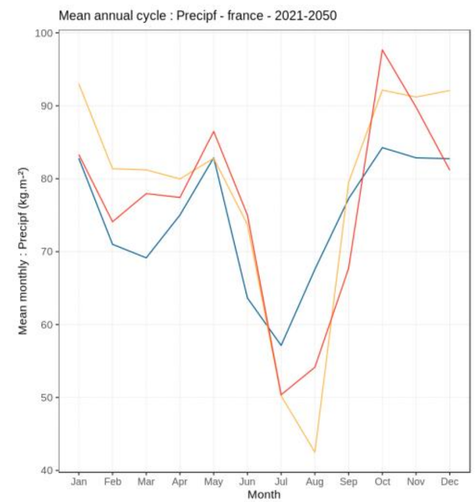
Perspectives

- Application of ADAMONT for **entire France** – First results

Change RCP 4.5 2021-2050 vs. HISTORICAL 1976-2005 (%)



Precipitation
SMHI-RCA4 /
MPI-M-MPI-ESM-LR



Blue: HISTORICAL 1976-2005
Yellow: RCP 4.5 2021-2050
Red : RCP 8.5 2021-2050

Perspectives

- Application of ADAMONT for impact of **climate change on mountain snow conditions over Europe – *Copernicus C3S SIS « European Tourism »***

  <u>**Objective:**</u> **Providing climate projections for mountain areas of Europe applicable for assessing natural and managed snow conditions (grooming, snowmaking).**

  Contribute to the **Copernicus C3S Sectoral Information System "European Tourism"**

  Use of the **UERRA5.5 km reanalysis** as an observation database

Copernicus Climate Change Service

Copernicus Climate Change Service: European Tourism

C3S European Tourism is an EU Copernicus Climate Change Service (C3S) contract led by TEC Conseil together with 11 sub-contractors across Europe.

ON BEHALF OF ECMWF FOR THE EUROPEAN COMMISSION

Perspectives

- Application of ADAMONT for **seasonal-to-decadal prediction**

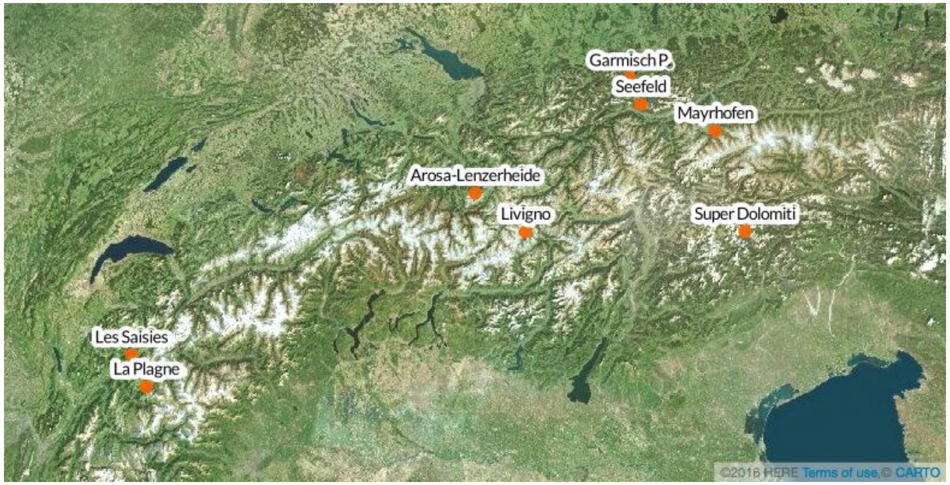
  - *H2020* ***PROSNOW*** *(2017-2020)*

Objective: Coupling seasonal forecast system with snow models accounting for snow management

Seasonal forecast data (Copernicus Climate Change Services) **downscaled** and **adjusted to ski resorts conditions** using the meteorological records available

Downscaled predictions used **as such** (e.g. forecast of conditions appropriate for snowmaking) or to **drive snowpack models** with the simulation of **processes on ski slope**s (grooming, snowmaking)

→ integrated vision of future state of snow on ski slopes at submonthly to seasonal time scale, depending on the **management decision** (e.g. with and without snowmaking)



http://prosnow.org/

Perspectives

- Application of ADAMONT for **seasonal-to-decadal prediction**

  *- ERA4CS **MEDSCOPE** (2017-2020)*

Objective: Provide climate forecasts in the Mediterranean region on seasonal-to-decadal time scales tailored for sectoral applications

Use of ADAMONT: seasonal forecast data (e.g. Copernicus Climate Change Service) will be **downscaled** and **adjusted** using UERRA reanalysis data to basin-scale areas for **applications in hydrology and agriculture**

ADAMONT will help derive consistent time series for precipitation, temperature, specific humidity and radiation

Final products: **ensemble seasonal forecasts** of impact variables (e.g. number of days with low flow for dam management)

ERA4CS European Research Area for Climate Services

MEDSCOPE MEDiterranean Services Chain based On climate PrEdictions

https://www.medscope-project.eu/

Perspectives

- Application of ADAMONT for **seasonal-to-decadal prediction**

  - H2020 ***EUCP*** *(2018-2021)*

Main objectives:

1. Development of an innovative **ensemble climate prediction system** based on high-resolution climate models for Europe for the near-term (1-40 years), with improved methods to characterise **uncertainty**, seamlessly **blend decadal predictions and projections**, regional **downscaling**, and **evaluation** against observations
2. Production of consistent, authoritative and actionable climate information. **Co-designed with users**, to support climate-related risk assessments and climate change adaptation programmes
3. Demonstration of the **value** of this prediction system through **high impact extreme weather events** in the near past and near future
4. Development and publication of **methodologies**, good practice and **guidance** for producing and using authoritative climate predictions for 1-40 year timescale

EUCP
European Climate Prediction system

https://www.eucp-project.eu/

Conclusions

Explicit **ensemble-based** model chain from global to regional to local impacts of climate change (atmospheric & snow conditions)

Quantitative analysis based on explicit computation of continuous scenarios 1950-2100.
→ Sustained **interannual variability**, **differences between RCPs** visible after 2050

Future application to **entire France**, for impact of **climate change on mountain snow conditions** and to **seasonal/decadal prediction**

Data available for further impact studies: managed snow, glacier mass balance, hydrology, ecosystem response, etc.

Thank you!

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